Technical Note on CERES EBAF Ed2.6

TOA Outgoing Longwave Radiation (rlut)

1. Intent of This Document and POC

1a) This document is intended for users who wish to compare satellite derived observations with climate model output in the context of the CMIP5/IPCC historical experiments. Users are not expected to be experts in satellite derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model output. References are provided at the end of this document to additional information.

This NASA dataset is provided as part of an experimental activity to increase the usability of NASA satellite observational data for the modeling and model analysis communities. This is not a standard NASA satellite instrument product, but does represent an effort on behalf of data experts to identify a product that is appropriate for routine model evaluation. The data may have been reprocessed, reformatted, or created solely for comparisons with climate model output. Community feedback to improve and validate the dataset for modeling usage is appreciated. Email comments to HQ-CLIMATE-OBS@mail.nasa.gov .

Dataset File Name (as it appears on the ESG):

rlut_CERES-EBAF_L4_Ed2-6_200003-201012.nc

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units:	TOA Outgoing Longwave Radiation (rlut), Wm^{-2}
Spatial resolution:	1°x1° latitude by longitude
Temporal resolution and extent:	Monthly averaged from 03/2000 to 12/2010
Coverage:	Global

3. Data Origin

CERES instruments fly on the Terra (descending sun-synchronous orbit with an equator crossing time of 10:30 A.M. local time) and Aqua (ascending sun-synchronous orbit with an equator crossing time of 1:30 P.M. local time) satellites. Each CERES instrument measures filtered radiances in the shortwave (SW; wavelengths between 0.3 and 5 μm), total (TOT; wavelengths between 0.3 and 200 μm), and window (WN; wavelengths between 8 and 12 μm) regions. To correct for the imperfect spectral response of the instrument, the filtered radiances are converted to unfiltered reflected solar, unfiltered emitted terrestrial longwave (LW) and window (WN) radiances (Loeb et al. 2001). Since there is no LW channel on CERES, LW daytime radiances are determined from the difference between the TOT and SW channel radiances. Instantaneous top-of-atmosphere (TOA) radiative fluxes are estimated from unfiltered radiances using empirical angular distribution models (ADMs; Loeb et al. 2003, 2005) for scene types identified using retrievals from Moderate Resolution Imaging Spectrometer (MODIS) measurements (Minnis et al. 2011). Monthly mean fluxes are determined by spatially averaging the instantaneous values on a 1º×1º grid, temporally interpolating at 1-h increments for each hour of every month, and then averaging all hour boxes in a month. Level-3 processing is performed on a nested grid, which uses 1° equal-angle regions between 45°N and 45°S, and maintains area consistency at higher latitudes. The fluxes are then output to a complete 360x180 1°×1° grid created by replication.

Monthly regional CERES LW TOA fluxes in the CMIP5 archive are from the CERES Energy Balanced and Filled (EBAF) Ed2.6 data product (Loeb et al., 2009). LW TOA fluxes in EBAF Ed2.6 are derived from the Terra CERES_SYN1deg-lite_Ed2.6 data product for March 2000–December 2010. In SYN1deg, LW radiative fluxes between CERES observation times are determined by supplementing the CERES observations with data from 5 geostationary satellites that sample every 3 hours for all longitudes between 60°S and 60°N, thus providing the most temporally and spatially complete CERES dataset for Terra or Aqua. Doelling et al. (2011) provides a detailed description of how broadband TOA fluxes are derived from geostationary data and combined with CERES observations.

As in previous versions of EBAF (Loeb et al., 2009), the CERES SW and LW fluxes in EBAF Ed2.6 are adjusted within their range of uncertainty to remove the inconsistency between average global net TOA flux and heat storage in the earth–atmosphere system, as determined primarily from ocean heat content anomaly (OHCA) data. In the current version, the global annual mean values are adjusted such that the 2006–2010 mean net TOA flux is 0.58±0.38 Wm^{-2} (uncertainties at the 90% confidence level). The uptake of heat by the Earth for this period is estimated from the sum of: (i) 0.47±0.38 Wm^{-2} from the slope of weighted linear least square fit to ARGO OHCA data (Roemmich et al., 2009) to a depth of 1800 m analyzed following Lyman and Johnson (2008); (ii) 0.07±0.05 Wm^{-2} from ocean heat storage at depths below 2000 m using data from 1981–2010 (Purkey and Johnson, 2010), and (iii) 0.04±0.02 Wm^{-2} from ice warming and melt, and atmospheric and lithospheric warming (Hansen et al., 2005; Trenberth, 2009).

4. Validation and Uncertainty Estimate

Regional monthly mean LW TOA fluxes are derived from Level-1 and -2 data. The Level-1 data correspond to calibrated radiances. Here we use the latest CERES gains and time-dependent spectral response function values (Thomas et al., 2010, Loeb et al., 2011). The Level-2 TOA fluxes are instantaneous values at the CERES footprint scale. Their accuracy has been evaluated in several papers (Loeb et al., 2006; Loeb et al., 2007; Kato and Loeb, 2005). The SYN1deg product used is evaluated in Doelling et al. (2011).

Figs. 1a and 1b provide regional plots of mean LW TOA flux and interannual variability for the month of March based upon all March months between 2000 and 2010. The regional standard deviation ranges from near zero at the poles to 30 Wm^{-2} in the equatorial Pacific Ocean region. Considering all 1°x1° regions between 90°S×90°N, the overall regional standard deviation in LW TOA flux is 17 Wm^{-2}, and the overall global mean LW TOA flux is 238 Wm^{-2}.

The uncertainty in 1°x1° regional LW TOA flux is evaluated using data from 07/2002-12/2010, when CERES instruments on both Terra and Aqua were operating. We compare regional fluxes from Terra and Aqua SYN1deg Ed2B products directly in Fig. 2. The overall mean difference is 0.05 Wm^{-2} and regional RMS difference is 2 Wm^{-2}. Regional differences can reach 5 Wm^{-2} in isolated regions of convection over south and central Africa and in the west Pacific Ocean region (Fig. 1b).

Table 1 compares global TOA averages for EBAF Ed2.6 with earlier versions EBAF Ed1.0 and EBAF Ed2.5. All-sky LW TOA flux in Ed2.6 is 0.3 Wm^{-2} greater than Ed1.0 and Ed2.5. The main difference between EBAF Ed2.6 and the earlier versions is that Ed2.6 applies geodetic weighting when averaging globally while geocentric weighting is assumed in EBAF Ed2.5.

Table 1 Global mean TOA fluxes from EBAF Ed1.0, EBAF Ed2.5 and EBAF Ed2.6 for March 2000–February 2005, March 2000–February 2010, and January 2006–December 2010.

	March 2000–February 2005		
	EBAF Ed1.0	EBAF Ed2.5	EBAF Ed2.6
Incoming Solar	340.0	340.2	340.5
LW (all-sky)	239.6	239.6	239.9
SW (all-sky)	99.5	99.7	100.0
Net (all-sky)	0.85	0.85	0.55
LW (clear-sky)	269.1	266.2	266.5
SW (clear-sky)	52.9	52.4	52.6
Net (clear-sky)	18.0	21.5	21.4
	March 2000–February 2010		
	EBAF Ed1.0	EBAF Ed2.5	EBAF Ed2.6
Incoming Solar		340.1	340.4
LW (all-sky)		239.6	239.9
SW (all-sky)		99.5	99.9
Net (all-sky)		1.0	0.59
LW (clear-sky)		266.0	266.4
SW (clear-sky)		52.4	52.5
Net (clear-sky)		21.6	21.5
	January 2006–December 2010		
	EBAF Ed1.0	EBAF Ed2.5	EBAF Ed2.6
Incoming Solar			340.3
LW (all-sky)			239.8
SW (all-sky)			99.9
Net (all-sky)			0.58
LW (clear-sky)			266.1
SW (clear-sky)			52.5
Net (clear-sky)			21.7

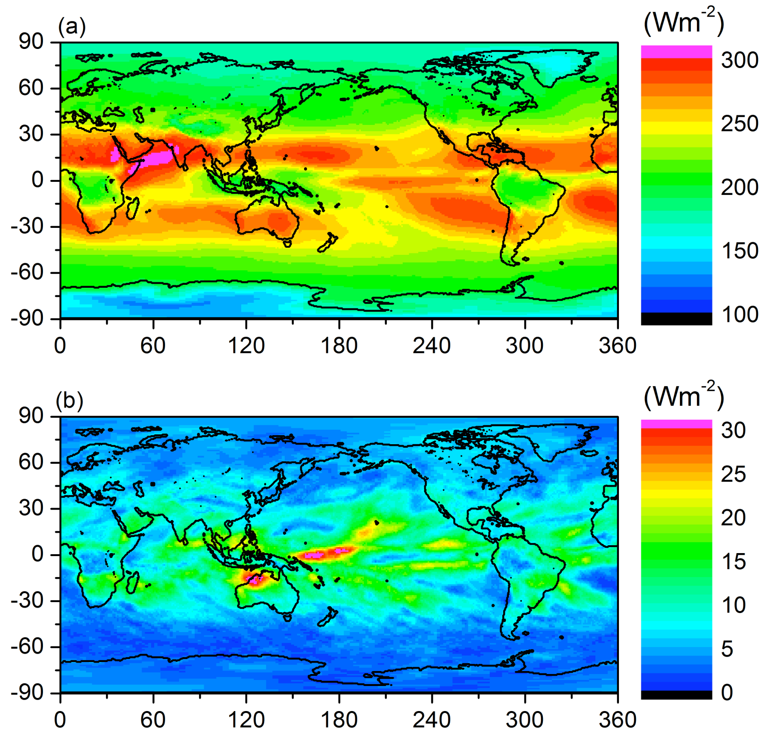

Figure 1 (a) Average and (b) standard deviation of LW TOA flux determined from all March months from 2000–2010 using the CERES EBAF2.5B product.

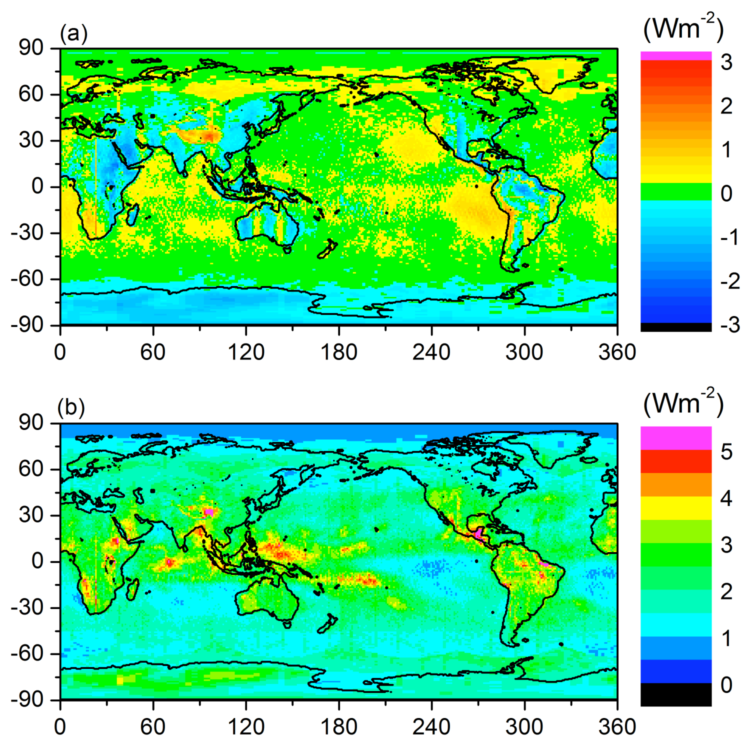

Figure 2 (a) Bias and (b) RMS difference between LW TOA fluxes from Terra and Aqua SYN1deg Ed2.6 data products.

5. Considerations for Model-Observation Comparisons

As noted in the previous section, the CERES monthly LW TOA fluxes account for diurnal cycle. Since the CERES instruments provide global coverage daily, monthly mean regional fluxes are based upon complete daily samples over the entire globe.

Since TOA flux represents a flow of radiant energy per unit area, and varies with distance from the earth according to the inverse-square law, a reference level is also needed to define satellite-based TOA fluxes. From theoretical radiative transfer calculations using a model that accounts for spherical geometry, the optimal reference level for defining TOA fluxes in radiation budget studies for the earth is estimated to be approximately 20 km. At this reference level, there is no need to explicitly account for horizontal transmission of solar radiation through the atmosphere in the earth radiation budget calculation. In this context, therefore, the 20-km reference level corresponds to the effective radiative ''top of atmosphere'' for the planet. Since climate models generally use a plane-parallel model approximation to estimate TOA fluxes and the earth radiation budget, they implicitly assume zero horizontal transmission of solar radiation in the radiation budget equation, and do not need to specify a flux reference level. By defining satellite-based TOA flux estimates at a 20-km flux reference level, comparisons with plane-parallel climate model calculations are simplified since there is no need to explicitly correct plane-parallel climate model fluxes for horizontal transmission of solar radiation through a finite earth. For a more detailed discussion of reference level, please see Loeb et al. (2002).

6. Instrument Overview

See the first paragraph of Section 3 for an overview of the CERES instruments on the Terra and Aqua satellites.

7. References

The full version of CERES EBAF Ed2.6 is available from the following ordering site:

http://ceres.larc.nasa.gov/order_data.php

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8. Revision History

[Document changes in the dataset and the technical note if a new version replaces an older version published on the ESG.]

Rev 0 – 08/09/2011 - This is a new document/dataset